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Helping Domain Experts Build Phrasal Speech Translation Systems

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Abstract. We present a new platform, "Regulus Lite", which supports rapid development and web deployment of several types of phrasal speech translation systems using a minimal formalism. A distinguishing feature is that most development work can be performed directly by domain experts. We motivate the need for platforms of this type and discuss three specific cases: medical speech translation, speech-to-sign-language translation and voice questionnaires. We briefly describe initial experiences in developing practical systems.

Keywords: Speech translation, medical translation, sign language translation, questionnaires, web

1 Introduction and motivation

In this paper, we claim that there is a place for limited-domain rule-based speech translation systems which are more expressive than fixed-phrase but less expressive than general syntax-based transfer or interlingua architectures. We want it to be possible to construct these systems using a formalism that permits a domain expert to do most of the work and immediately deploy the result over the web. To this end, we describe a new platform, "Regulus Lite", which can be used to develop several different types of spoken language translation application.

A question immediately arises: are such platforms still relevant, given the existence of Google Translate (GT) and similar engines? We argue the answer is yes, with the clearest evidence perhaps coming from medical speech translation. Recent studies show, unsurprisingly, that GT is starting to be used in hospitals, for the obvious reason that it is vastly cheaper than paid human interpreters [4]; on the other hand, experience shows that GT, which has not been trained for this domain, is seriously unreliable on medical language. A recent paper [23]

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describes the result of a semi-formal evaluation, in which it was used to translate ten text sentences that a doctor might plausibly say to a patient into 26 target languages. The bottom-line conclusion was that the results were incorrect more than one time in three.

Doctors are thus with good reason suspicious about the use of broad-coverage speech translation systems in medical contexts, and the existence of systems like MediBabble[1] gives further grounds to believe that there is a real problem to solve here. MediBabble builds on extremely unsophisticated translation technology (fixed-phrase, no speech input), but has achieved considerable popularity with medical practitioners. In safety-critical domains like medicine, there certainly seem to be many users who prefer a reliable, unsophisticated system to an unreliable, sophisticated one. MediBabble is a highly regarded app because the content is well-chosen and the translations are known to be good, and the rest is viewed as less important. The app has been constructed by doctors; a language technologist's reaction is that even if GT may be too unreliable for use in hospitals, one can hope that it is not necessary to go back to architectures quite as basic as this. A reasonable ambition is to search for a compromise which retains the desirable property of producing only reliable output prechecked by professional translators, but at the same time supports at least some kind of productive use of language, and also speech recognition.

A second type of application which has helped motivate the development of our architecture is speech-to-sign-language translation. Sign languages are low-resource, a problem they share with many of the target languages interesting in the context of medical speech translation. In addition, since they are non-linear, inherently relying on multiple parallel channels of communication including hand movement, eye gaze, head tilt and eyebrow inflection [21], it is not possible to formalise translation as the problem of converting a source-language string into a target-language string. It is in principle feasible to extend the SMT paradigm to cover this type of scenario, but currently available mainstream SMT engines do not do so. As a result, most previous SMT approaches to sign language machine translation, such as [27] and [19], have used unilinear representations of the sign languages involved. If we want to build sign-language translators which can produce high-quality output in the short-term, rule-based systems are a logical choice.

A third application area where this kind of approach seems appropriate is interactive multilingual questionnaires. Particularly in crisis areas, it is often useful for personnel in the field to be able to carry out quick surveys where information is elicited from subjects who have no language in common with the interviewer [26]. Again, applications of this kind only need simple and rigid coverage, but accurate translation and rapid deployability are essential, and practically interesting target languages are often underresourced.

In the rest of the paper, we describe Regulus Lite, showing how it can be used as an economical tool for building spoken language translation applications at least for the three domains we have just mentioned. The main focus is

[1] `http://medibabble.com/`

application content development. §2 gives an overview of the platform and the rule formalism. §3 presents specific details on medical speech translation, sign language translation and voice questionnaires, and briefly sketches the initial applications. §4 presents some initial evaluation results for the voice questionnaire app, currently the most advanced one. The final section concludes.

2 The platform

The Regulus Lite platform supports rapid development and web deployment for three types of small to medium vocabulary speech translation applications: plain translation, sign language translation, and voice questionnaires. We briefly describe each of these:

Plain translation The simplest case: the source language user speaks and the system displays its understanding of what the user said (a paraphrase of what was recognised). If the source language user approves the paraphrase, a target language translation is produced.

Sign language translation Similar to plain translation, but the output is rendered in some form of sign language, using a signing avatar.

Voice questionnaires The content is organized as a form-filling questionnaire, where the interviewer poses the questions in spoken form, after which they are translated into the target language and presented to the subject. There are typically many possible questions for each field in the questionnaire. The subject responds by pressing one of a question-dependent set of buttons, each of which is labelled with a possible answer.

A basic assumption is that the content will be in the form of flat phrasal regular expression grammars. Reflecting this, content is specified using two basic constructions, `TrPhrase` (phrases) and `TrLex` (lexical items). Each construction combines one or more `Source` language patterns and at most one `Target` language result for each relevant target language, and indicates that the `Source` line can be translated as the `Target`. A trivial example[2] might be

```
TrPhrase $$top
Source ( hello | hi )
Target/french Bonjour
EndTrPhrase
```

A slightly more complex example, which includes a `TrLex`, might be

```
TrPhrase $$top
Source i ( want | would like ) $$food-or-drink ?please
Source ( could | can ) i have  $$food-or-drink ?please
Target/french je voudrais $$food-or-drink s'il vous plaît
EndTrPhrase

TrLex $$food-or-drink source="a (coca-cola | coke)" french="un coca"
```

[2] The notation has been changed slightly for expositional purposes.

Here, the variable `$$food-or-drink` in the first rule indicates a phrase that is to be translated using the second rule.

In order to decouple the source language and target language development tasks, `TrPhrase` and `TrLex` units are split into pieces placed in separate language-specific files, one for the source language and one for each target language. The connecting link is provided by a canonical version of the source language text (the portions marked as `Target/english` or `english=`). Thus the `TrPhrase` and `TrLex` units above will be reconstituted from the source-language (English) pieces

```
TrPhrase $$top
Source i ( want | would like ) $$food-or-drink ?please
Source ( could | can ) i have  $$food-or-drink ?please
Target/english i want $$food-or-drink please
EndTrPhrase

TrLex $$food-or-drink source="a (coca-cola | coke)" english="a coke"
```

and the target language (French) pieces

```
TrPhrase $$top
Target/english i want $$food-or-drink please
Target/french je voudrais $$food-or-drink s'il vous plaît
EndTrPhrase

TrLex $$food-or-drink english="a coke" french="un coca"
```

The development process starts with the source language developer writing their piece of each unit, defining the application's coverage. A script then generates "blank" versions of the target language files, in which the canonical source lines are filled in and the target language lines are left empty; so the French target language developer will receive a file containing items like the following, where their task is to replace the question marks by translating the canonical English sentences.

```
TrPhrase $$top
Target/english i want $$food-or-drink please
Target/french ?
EndTrPhrase

TrLex $$food-or-drink source="a coke" french="?"
```

As the source language developer adds more coverage, the "blank" target language files are periodically updated to include relevant new items.

The content can at any time be compiled into various pieces of runtime software, of which the most important are an application-specific grammar-based speech recogniser and a translation grammar; the underlying speech recognition engine used in the implemented version of the platform is Nuance Recognizer version 10.2. These generated software modules can be immediately uploaded to a webserver, so that the system is redeployable on a time scale of a few minutes. Applications can be hosted on mobile platforms — smartphones, tablets or laptops — linked over a 3G connection to a remote server, with recognition performed on the server [12]. The deployment-level architecture of the platform is adapted from that of the related platform described in [25], and offers essentially the same functionality.

3 Types of application

3.1 Medical translation

As already mentioned, medical speech translation is one of the areas which most strongly motivates our architecture. Several studies, including earlier projects of our own [23,30], suggest that doctors are dubious about the unpredictability of broad-coverage SMT systems and place high value on translations which have been previously validated by professional translators. Other relevant factors are that medical diagnosis dialogues are sterotypical and highly structured, and that the languages which pose practical difficulties are ones badly served by mainstream translation systems.

The practical problems arise from the fact that the Lite formalism only supports regular expression translation grammars. The question is thus what constituents we can find which it is safe always to translate compositionally. It is clear that many constituents cannot be treated in this way. Nonetheless, it turns out that enough of them can be translated compositionally that the grammar description is vastly more efficient than a completely enumerative framework; most adjuncts, in particular PPs and subordinate clauses, can be regarded as compositional, and it is often possible to treat nouns and adjectives compositionally in specific contexts.

We are currently developing a prototype medical speech translator in a collaboration with a group at Geneva's largest hospital[3]. Initial coverage is organised around medical examinations involving abdominal pain, with the rules loosely based on those developed under an earlier project [2]. Translation is from French to Spanish, Italian and Arabic[4]. A typical source language rule (slightly simplified for presentational purposes) is

```
TrPhrase $$top
Source ?$$PP_time la douleur est-elle ?$$adv $$qual ?$$PP_time
Source ?$$PP_time avez-vous ?$$adv une douleur $$qual
Source ?$$PP_time ?(est-ce que) la douleur est ?$$adv $$qual ?$$PP_time
Target/french la douleur est-elle ?$$adv $$qual ?$$PP_time
EndTrPhrase
```

[3] Hôpitaux Universitaires de Genève

[4] Tigrinya will be added soon.

Here, the French `Source` lines give different variants of *la douleur est-elle $$qual* ("Is the pain $$qual?"), for various substitutions of the transfer variable `$$qual` (*vive*, "sharp"; *difficile à situer*, "hard to localize"; *dans l'angle costal*, "in the intercostal angle", etc). Each variant can optionally be modified by an adverb (`$$adv`) and/or a temporal PP (`$$PP_time`). Thus the questions covered will be things like *avez-vous souvent une douleur vive le matin?* ("do you often experience a sharp pain in the morning?") As the rule illustrates, there are typically many possible ways of formulating the question, all of which map onto a single canonical version. The target language translators work directly from the canonical version.

The current prototype represents the result of about one person-month of effort, nearly all of which was spent on developing the source side rules. Coverage consists of about 250 canonical patterns, expanding to about 3M possible source side sentences; the source language vocabulary is about 650 words. Creating a set of target language rules only involves translating the canonical patterns, and is very quick; for example, the rules for Italian, which were added at a late stage, took a few hours.

Speech recognition is anecdotally quite good: sentences which are within coverage are usually recognised, and correctly recognised utterances are always translated correctly. The informal opinion of the medical staff who have taken part in the experiments is that the system is already close to the point where it would be useful in real hospital situations, and clearly outperforms Google Translate within its intended area of application. We are in process of organising a first formal evaluation and expect to be able to report results in 2016.

3.2 Sign language translation

The rapidly emerging field of automatic sign language translation poses multiple challenges [3,5,7,9,13,16,17,18,20,22,28]. An immediate problem is that sign languages are very resource-poor. Even for the largest and best-understood sign languages, ASL and Auslan, the difficulty and expense of signed language annotation means there is an acute shortage of available corpus data[5]; for most of the world's estimated 120 sign languages [31], there are no corpora at all. In addition, there are often no reliable lexica or grammars and no native speakers of the language with training in linguistics.

Sign languages also pose unique challenges not shared with spoken languages. As already mentioned, they are inherently non-linear; even though the most important component of meaning is conveyed by the hands/arms (the *manual activity*), movements of the shoulders, head, and face (the *non-manual components*) are also extremely important and are capable of assuming functions at all linguistic levels [6]. Commonly cited examples include the use of head shakes/eyebrow movements to indicate negation and eye gaze/head tilt to convey topicalization [21,14]. Anecdotally, signers can to some extent understand

[5] The largest parallel corpus used in sign language translation that we know of has about 8 700 utterances [11].

signed language which only uses hand movements, but it is regarded as unnatural and can easily degenerate into incomprehensibility [29]; quantitatively, controlled studies show that the absence of non-manual information in synthesized signing (sign language animation) leads to lower comprehension scores and lower subjective ratings of the animations [15]. In summary, it is unsatisfactory to model sign language translation with the approximation most often used in practice: represent a signed utterance as a sequence of "glosses" (identifiers corresponding to hand signs), and consider the translation problem as that of finding a sequence of glosses corresponding to the source language utterance [8]. This approximation is unfortunately necessary if mainstream SMT engines are to be used.

For the above reasons and others, it is natural to argue that current technology requires high-quality automatic sign language translation to use rule-based methods in which signed utterances are represented in nonlinear form [13]. Our treatment conforms to these intuitions and adapts them to the minimalistic Lite framework. Following standard practice in the sign language linguistics literature, a signed utterance is represented at the linguistic level as a set of aligned lists, one for each parallel output stream: at the moment, we use six lists respectively called `gloss` (hand signs), `head` (head movements like nodding or shaking), `gaze` (direction of eye gaze), `eyebrows` (raising or furrowing of eyebrows), `aperture` (widening or narrowing of eyes) and `mouthing` (forming of sound-like shapes with the mouth).

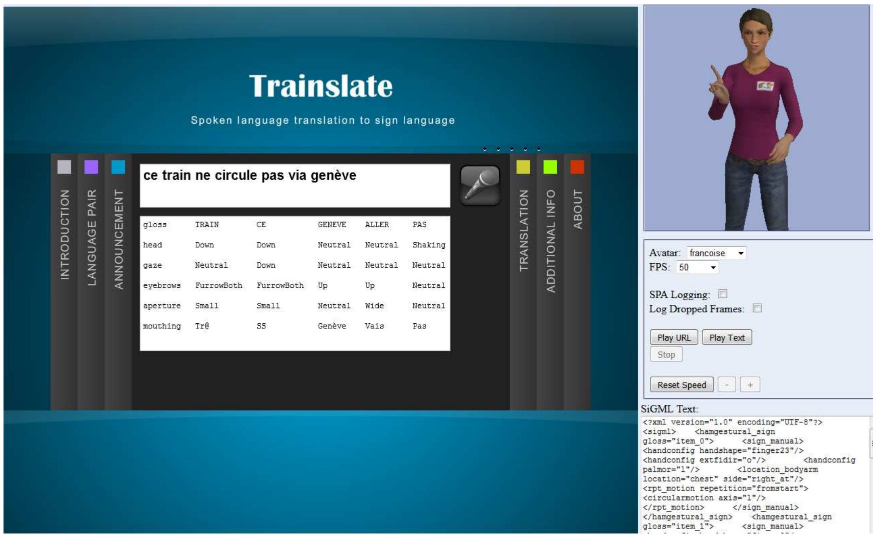
gloss	TRAIN1NORMAL	CE	GENEVE	ALLER	PAS
head	Down	Down	Neutral	Neutral	Shaking
gaze	Neutral	Down	Neutral	Neutral	Neutral
eyebrows	FurrowBoth	FurrowBoth	Up	Up	Neutral
aperture	Small	Small	Neutral	Wide	Neutral
mouthing	Tr@	SS	Genève	Vais	Pas

Fig. 1. Sign table representation of an utterance in Swiss French Sign Language meaning "This train does not go through Geneva".

The examples we show below are taken from our initial application, which translates train service announcements from spoken French to Swiss French sign language. A typical sign table is shown in Figure 1; translation from speech to sign is performed in three stages, with sign tables like these acting as an intermediate representation or pivot. As before, the first stage is to use speech recognition to produce a source language text string[6]. In the second, the source language string is translated into a sign table. Finally, the sign table is translated into a representation in SiGML [9], which can be fed into a signing avatar; in the current version of the system, we use JASigning [10]. The image below shows the

[6] This is a slight oversimplification; in actual fact, recognition passes an n-best hypothesis list. The complications this introduces are irrelevant in the present context.

user interface. On the left, we have, from top to bottom, the recognition result and the sign table; on the right, the avatar, the avatar controls and the SiGML.



The issues that are of interest here are concerned with the text to sign table translation stage; once again, the central challenge is to create a formalism which can be used by linguists who are familiar with the conventions of sign language linguistics, but not necessarily with computational concepts. The formalism used is a natural generalization of the one employed for normal text-to-text translation; the difference is that the output is not one list of tokens, but six aligned lists, one for each of the output streams. For practical reasons, since correct alignment of the streams is crucial, it is convenient to write rules in spreadsheets and use the spreadsheet columns to enforce the alignment.

The non-obvious aspects arise from the fact that phrasal sign translation rules in general fail to specify values for all the output streams, with the values of the other streams being filled in by phrases higher up in the parse tree. Figure 2 illustrates, continuing the example from the previous figure. The lexical entry for *genève* only specifies values for the `gloss` and `mouthing` lines. When the rules are combined to form the output shown in Figure 1, the value of `eyebrows` associated with the sign glossed `GENEVE` is inherited from the phrase above, and thus becomes `FurrowBoth`.

The process by which sign tables are translated into SiGML is tangential to the main focus of this paper, so we content ourselves with a brief summary. The information required to perform the translation is supplied by three lexicon spreadsheets, maintained by the sign language expert, which associate glosses and other identifiers appearing in the sign table with SiGML tags and strings written in HamNoSys [24], a popular notation for describing signs. The rule compiler checks the spreadsheets for missing entries, and if necessary adds new "blank" rows, using a model similar to that described in §2.

```
TrPhrase $$top
Source ce train ne circule pas via $$station
Target/gloss     TRAIN      CE         $$station    ALLER   PAS
Target/head      Down       Down       Neutral      Neutral Shaking
Target/gaze      Neutral    Down       Neutral      Neutral Neutral
Target/eyebrows  FurrowBoth FurrowBoth Up           Up      Neutral
Target/aperture  Small      Small      Neutral      Wide    Neutral
Target/mouthing  Tr@        SS         $$station    Vais    Pas
EndTrPhrase

TrLex $$station source="genève" gloss="GENEVE" mouthing="Genève"
```

Fig. 2. Examples of top-level translation rule and lexical entry for the train announcement domain. The rule defines a phrase of the form *ce train ne circule pas via* ⟨*station*⟩ ("this train does not travel via ⟨station⟩". The lexical entry defines the translation for the name *genève* ("Geneva"). Only gloss and mouthing forms are defined for the lexical item.

3.3 Voice questionnaires

We have already touched on the special problems of interactive voice questionnaires in the introduction. The overall intention is to add speech input and output capablities to the RAMP data gathering questionnaire framework [26]. The questionnaire definition encodes a branching sequence of questions, where the identity of the following question is determined by the answer to the preceding one. The display shows the person administering the questionnaire the field currently being filled; they formulate a question and speak it in their own language. In general, there are many questions which can be used to fill a given field, and the interviewer will choose an appropriate one depending on the situation. A basic choice, which affects most fields, is between a WH and a Y/N question. For example, if the interviewer can see recently used cooking utensils in front of him, it is odd to ask the open-ended WH-question "Where do you do the cooking?"; a more natural choice is to point and ask the Y/N confirmation question "Is cooking done in the house?"

As usual, the app performs speech recognition, gives the interviewer confirmation feedback, and speaks the target language translation if they approve. It then displays a question-dependent set of answer icons on the touch-screen. The respondent answers by pressing one of them; each icon has an associated voice recording, in the respondent language, identifying its function. Speech recognition coverage, in general, is limited to the specific words and phrases defined in the application content files. In this particular case, it is advantageous to limit it further by exploiting the tight constraints inherent in the questionnaire task, so that at any given moment only the subset of the coverage relevant to the current question is made available.

As far as rule formalisms are concerned, the questionnaire task only requires a small extension of the basic translation framework, in order to add the extra information associated with the questionnaire structure. The details are straightforward and are described in [1].

The next section uses an initial prototype of a voice questionnaire app ("AidSLT") to perform a simple evaluation of speech recognition performance. The questionnaire used for the evaluation contained 18 fields, which together supported 75 possible translated questions, i.e. an average of about 4 translated questions per field. The recognition grammar permitted a total of 11 604 possible source language questions, i.e. an average of about 155 source language questions per translated question.

4 Initial evaluation

The initial AidSLT questionnaire was tested during the period March–July 2015 by seven humanitarian workers with field experience and knowledge of household surveys. The main focus of the evaluation was on the recognition of speech input by English-speaking interviewers. Subjects were presented with a simulation exercise that consisted in administering a household survey about malaria preventive measures to an imaginary French-speaking respondent. Instructions were sent by e-mail in the form of a PDF file. The subjects logged in to the application over the web from a variety of locations using password-protected accounts. Each subject ran the questionnaire once; annotations were added in the script so that several questions produced a popup which asked the subject to rephrase their initial question.

We obtained a total of 137 correctly logged interactions[7], which were annotated independently by two judges. Annotators were asked to transcribe the recorded utterances and answer two questions for each utterance: a) whether the subject appeared to be reading the heading for the questionnaire field or expressing themselves freely, and b) whether the translation produced adequately expressed the question asked in the context of the questionnaire task. Agreement between the two judges was very good, with a Cohen's kappa of 0.786 and an Intraclass Correlation Coefficient of 0.922.

The bottom-line result was that between 77 and 79 of the sentences were freely expressed (56–58%) and only 10 produced incorrect translations (7%), despite a Word Error Rate of about 29%. All the incorrect translations were of course due to incorrect recognition. We find this result encouraging; the architecture appears to be robust to bad recognition and exploits the constrained nature of the task well.

5 Conclusions and further directions

We have described a platform that supports rapid development of a variety of limited-domain speech translation applications. Applications can be deployed on

[7] One subject misunderstood the instructions, one had severe audio problems with their connection, and a few utterances were spoiled by incorrect use of the push-to-talk interface.

the web and run on both desktop and mobile devices. The minimal formalism is designed to be used by domain experts who in general will not be computer scientists.

Although the translation platform is still at an early stage of development, experiences so far are positive; comparisons with our spoken CALL platform [25], which uses the same recognition architecture and has already been tested successfully on a large scale, leave us optimistic that we will achieve similar results here.

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